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HUMAN RESOURCES

CONTRIBUTIONS OF PLATFORM MOTION TO SIMULATOR TRAINING EFFECTIVENESS:
STUDY II – AEROBATICS

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NOTICE

This interim report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Dr. Elizabeth L. Martin was the principal investigator.

This technical report has been reviewed and is approved for publication.

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PREFACE

This report represents a portion of the research program of Project 1123, USAF Flying Training Development, Mr. James F. Smith, Project Scientist; Task 112301, Development of Performance Measurement Techniques for Air Force Flying Training, Dr. Elizabeth L. Martin, Task Scientist. This study was conducted by the Flying Training Division of the Air Force Human Resources Laboratory (AFSC) and supported by the 82d Flying Training Wing (ATC), Williams AFB, Arizona. The support rendered by the members of the 82d FTW Deputy for Operational Research Staff for the simulator training of the students made this study possible.

The research was greatly assisted by Capt Bruce Smith, Capt Rowe Stayton, and Mr. Richard Greatorex. Capt Smith developed the special data cards, defined the mission scenarios and training syllabus, and prepared the demonstrations used in the Advanced Simulator for Pilot Training (ASPT) phase of the study. Capt Stayton provided invaluable assistance throughout all phases of the study and served as the primary liaison with the flightline. Finally, Mr. Richard Greatorex was responsible for the multivariate data analyses. The technical expertise of these individuals, professional attitude, and patience contributed substantially to all phases of the study.

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I. INTRODUCTION

Advances in simulation technology have made available a variety of subsystems which purportedly enhance training effectiveness by increasing the fidelity or realism of the device. Synergistic platform motion systems having six degrees of freedom (DOF), G-seats, G-suits, and buffet systems are typical of fidelity-oriented hardware which attempt to provide realistic force-cueing information. It is well known that motion cues are not essential for effective simulator training, since pilots have been learning to fly with the aid of fixed-base devices for years. However, the extent to which these recently developed force-cueing systems add to the effectiveness of simulation training is unknown.

In a recent study, Martin and Waag (1978) investigated the incremental transfer effectiveness of platform-motion cueing for one specific application–Undergraduate Pilot Trainees transitioning to the T-37 aircraft. A transfer of training design was used to evaluate the contributions of a synergistic six-DOF platform motion system to the acquisition of basic contact, approach, and landing skills. To briefly summarize the study, 24 students transitioning to Undergraduate Pilot Training (UPT) were divided into three groups–Motion, No-Motion, and Control. The Motion and No-Motion groups received 10 instructional sorties in the Advanced Simulator for Pilot Training (ASPT) on a large number of basic contact tasks ranging in complexity from Straight-and-Level to the normal Overhead Pattern and Traffic Pattern Stalls. Students in the Control group received no ASPT pretraining. Short-term transfer was assessed for the Motion and No-Motion groups on two special data rides in the T-37 aircraft. Long-term transfer effects were provided by task frequency data collected on selected tasks for all groups on all flights through solo.

The major findings of the study were as follows: (a) no differences were found in simulator performance between the Motion and No-Motion groups; (b) significant learning occurred during simulator training for both groups; (c) no difference was found in performance between the Motion and No-Motion groups for any of the tasks on the two special data sorties flown in the T-37; (d) no significant differences were found between the Motion and No-Motion groups in the task frequency data, although there was a trend for the Motion group to perform slightly better; and (e) the two groups trained in the ASPT perform significantly better than the control group on all of the more advanced tasks. In conclusion, the data failed to reveal any significant or practical enhancement of training effectiveness as a result of the addition of platform motion.

One possible explanation of these findings is that, with the exception of stalls, motion cues were, for the most part, incidental or secondary cues. Typically, the magnitude of transfer effects expected from such incidental cues is small compared to that from primary cues. Moreover, there is not a great deal of motion cueing involved in these tasks in that the amount and/or magnitude of force cueing in the aircraft is relatively small. For this reason, it seemed necessary to extend the effort to aerobatic tasks in which motion cues are more prominent.

The objectives of the present study were: (a) to evaluate the effectiveness of the ASPT in providing simulation training of aerobatic maneuvers normally taught in the T-37 phase of UPT, (b) to evaluate the effectiveness of synergistic six-DOF platform motion in enhancing the transfer of training to the aircraft, and (c) to determine the effects of platform motion on the acquisition of aerobatic skills in the simulator.

II. METHOD

General Approach

A transfer of training paradigm was used in which two groups of USAF UPT students received training in the ASPT on selected aerobatic maneuvers. One group was trained in the absence

of platform motion cues, while the other group received the same training scenario in the presence of platform motion. These groups, Motion (M) and No-Motion (NM), respectively, received two blocks of instruction in the ASPT, each followed by performance evaluation in the aircraft. A third group received standard syllabus training on these maneuvers (i.e., no ASPT) and served as a Control group (C). The performance of the two experimental groups in the ASPT and the performance of all three groups in the T-37 were evaluated by T-37 instructor pilots (IPs).

Subjects

A total of 36 student pilots in the T-37 phase of UPT at Williams AFB, Arizona, participated in this study. Eighteen students from UPT Class 77-04 and 18 students from UPT Class 77-06 were selected at random from their respective classes with the restriction that foreign nationals were not allowed to participate.

Instructor Pilots

Sixteen T-37 IPs from the 96th FTS, Williams AFB, served as ASPT instructors. The instructors participated in the ASPT phase of training on a voluntary basis from flight sections not involved in the study, so that the ASPT IPs were not the same as the students' regularly assigned flightline instructors, but the latter were used during the aircraft portion of the study.

Equipment

Experimental training was accomplished in the ASPT. An overview of the aspects of the ASPT most relevant to the present study is presented in this section. Detailed descriptions of this device may be found in Gum, Albery and Basinger (1975). The ASPT is equipped with two T-37 cockpits. Each cockpit has a full field-of-view visual display of computer-generated images; a six-DOF, synergistic platform-motion system; and a 16-panel pneumatic G-seat on the left seat (student postion).

The visual display is projected through seven 36-inch cathode ray tubes (CRTs). The capacity for displaying visual image detail is fixed and shared between the two cockpits. A highly detailed scene, such as an airport, requires 90% to 100% of the display capacity; however, 50% of display capacity is adequate to display a generalized view from altitude, such as a horizon and surface texture patterns necessary for aerobatic training. The visual system uses an infinity optics display with the exit pupil located at the student's eye postiion. This arrangement results in an optimal visual scene from the student position, but a distorted scene from the IP position. From the normal position, the IP is unable to see the visual display immediately in front of the aircraft. The scene becomes less distorted as the IP scans laterally. If the head position is moved nearer to that of the student, the IP can increase the forward-looking view and reduce the distortion.

The platform motion system is driven by six hydraulic actuators, each with a travel capability of 60 inches. The platform motion system software was designed to provide translational and rotational acceleration onset cues to the student pilot position. The drive philosophy for the display of translational acceleration cues is intended to match the aircraft acceleration in magnitude and shape, whereas the display of onset rotational accelerations is driven by a cue-shaping philosophy. Some sustained acceleration cues can be simulated via platform movement with a subsystem called "gravity align," which positions the platform in an attempt to substitute for a portion of the external force vector. (The G-seat can also display sustained accelerating cues; however, it was not used in this study and will not be discussed.) The motion system also includes a special effects package which is used to display such cues as touchdown bump, runway rumble, aircraft buffet, speedbrake extension, and gear-down rumble.

The ASPT has the capability of real-time, automated measurement of the pilot's performance. Measurements can be made of pilot inputs, system outputs, and derived scores. A limited amount of this information can be displayed real-time in the cockpit via a monitor located to the right of the IP position and/or following the mission in hard copy form.

The ASPT is equipped with the capability to display a prerecorded demonstration of a maneuver. At the time of the study, the information was stored on magnetic tape which enabled a reproduction of the entire maneuver, including visual display, motion cues, instrument readings, rudder and throttle movements. Subsequently, this

capability has been transferred to disc to improve system reliability.

Two additional instructional capabilities of ASPT were utilized in the present study: problem freeze and reinitialization. The instructor can stop and hold the system at its current position by the use of the problem freeze feature. From this position, the instructor can continue flight from the "frozen" position or return to any chosen starting point by use of the reinitialization feature. Reinitialization allows the system to go to a designated position and configuration in a matter of seconds. These points are preprogrammed to correspond to optimal starting positions for most maneuvers, including cross-country positions, in the T-37 training program. The main utility of the freeze feature is in its instructional value, whereas the reinitialization is a time-saving feature which also allows for tighter experimental control over student practice.

The advanced instructor operator console (AIOS) is equipped with a Vector General monitor which has a spatial display option. This option can follow the flightpath of the simulated aircraft, which can be rotated around the x, y, or z axis. This image can be temporarily stored and then displayed after the mission for use in the debriefing.

Procedure

Subject Assignment. The subjects were randomly assigned to one of the three treatment conditions: (a) No-Motion, (b) six-DOF Motion, or (c) Control. A total of 36 subjects participated, with 12 subjects per group.

Instructor Pilot Training. All ASPT instructors received verbal and written briefings on the experimental procedures and the use of the ASPT with pertinent instructional features. In addition, the ASPT instructors rehearsed each scenario with a practice student. All aircraft instructor pilots assigned to one of the student subjects were briefed on the data recording format and received one session of data-taking practice in the ASPT, using prerecorded demonstrations of each candidate maneuver.

ASPT Training. Subjects assigned to the Motion and No-Motion groups received five training sorties in the ASPT. The instructional content of the ASPT sorties was identical for both groups with the only difference being whether or not the platform motion system was operative. Thus, all subjects in the Motion condition received all sorties in the presence of motion cues, while the subjects in the No-Motion condition received the same sortie content but with no platform motion. The G-seat was inoperative throughout the study. All training was accomplished under full field-of-view conditions with the visual scene content set at 50% edge capacity. The scene contained all section lines and mountains in the practice area.

Mission Content. The content of each sortie was specified in terms of the order of maneuver instruction and the number of repetitions per maneuver. Instruction on each new aerobatic maneuver was introduced by a prerecorded demonstration of that maneuver. Selected repetitions of a maneuver were designated as performance measurement trials during which the IP was prohibited from instructing the student. The five ASPT sorties were divided into two blocks: (a) Basic Aerobatics, and (b) Advanced Aerobatics. A summary of the total number of task repetitions and the content of each mission is found in Appendix A.

1. *Basic Aerobatics*. Each subject was required to complete at least the first aircraft sortie in the C23XX block (last pre-solo contact rides) prior to receiving ASPT training in the Basic Aerobatic maneuvers. The Basic block was completed prior to entry into the C25XX (Basic Aerobatics) aircraft missions. The Basic block of the ASPT instruction consisted of three missions. The first lasted approximately 1.5 hours and each of the last two approximately 1.0 hour. Following a brief ASPT familiarization period, instruction was given on four Basic Aerobatic maneuvers: (a) Aileron Roll, (b) Split S, (c) Loop, and (d) Lazy 8. An attempt was made to administer the missions on a daily basis. However, operational constraints required that the last two missions of the Basic block be given on the same day for some of the students. When the double mission was necessary, the missions were separated by at least 1 hour.

2. *Advanced Aerobatics*. Following completion of the C25XX aircraft block (Basic Aerobatics) and prior to initiation in the C27XX block (Advanced Aerobatics), the students received the ASPT block of instruction on the Advanced Aerobatics maneuvers of: (a)

Immelmann; (b) Barrel Roll; (c) Cuban 8; and (d) Cloverleaf. The Advanced ASPT block consisted of two missions, each approximately 1 hour in length. In most cases, the missions were administered one per day over a 2-day interval.

Performance Measurement. Periodically throughout the five ASPT sorties, the student's performance was evaluated. The IP rated the performance on a 12-point scale with the following characteristics: 1 to 3 representing an unsatisfactory performance; 4 to 6 representing a fair level; 7 to 9 reflecting a good; 10 to 12 reprenting an excellent performance. The criteria, unsatisfactory, fair, good, and excellent, are specified in the ATC training syllabus (July 1975). The categories correspond approximately to unsafe, minimum safety, proficient, and superior. These ratings were given immediately following the maneuver over an intercom system and were not available to the student.

In addition to these global evaluations, IPs were required to record specific information, such as entry airspeed, and bank at entry, and to give more detailed evaluations, such as pitch rate control and ground track control. These evaluations were recorded on special data cards developed specifically for the study. These data cards and the instructions for their use are presented in Appendixes B and C. Each IP received one data-taking practice session in the ASPT, using prerecorded demonstrations of each candidate maneuver.

An attempt was made to collect objective data in the ASPT, using the automated performance measurement system. However, numerous system failures resulted in large amounts of missing data. Furthermore, verification of the measurement system software for these tasks had not been completed at the time of the study. For these reasons, no attempt was made to analyze the data collected.

T-37 Training and Evaluation. All T-37 training was accomplished by each student's normal flightline instructor, in accordance with standard syllabus procedures. Each student received four instructional sorties for the Basic Aerobatics block (C25XX) and three for the Advanced Aerobatics block (C27XX). For each sortie, it was requested that the student fly at least one repetition of each of the four maneuvers trained for that block. Performance evaluations were accomplished, using the special data card forms described in Appendix B.

III. RESULTS

ASPT Training

All students completed the five ASPT training sorties. Two performance evaluations were obtained for each of the eight maneuvers, usually at the beginning and end of simulator training. The occurrence of these evaluations within the training sequence is given in Appendix A. For each evaluation, two types of information were recorded, the overall IP rating and the information required on the special data card (Appendix B). For each maneuver, the IP rating data were analyzed using split-plot analyses of variance (ANOVAs) with Motion vs. No-Motion as the between-subjects factor and with trials as the repeated measure. Missing data cells were estimated, using the least-squares technique described in Kirk (1968). Degrees of freedom in the affected ANOVAs were adjusted accordingly.

For each maneuver, a single-factor, multivariate ANOVA (MANOVA) was performed, using the individual measures recorded on the data card. The MANOVA was selected as the appropriate overall test, due to the unknown interdependencies among the individual measures. Stepdown univariate Fs were computed, in order to determine those variables which produced any overall effect. MANOVAs were computed for each repetition, as well as their combination, due to the non-availability of an analysis program which could handle repeated measures. Appendix D presents the descriptive statistics and results of the data analysis.

Results of the ANOVAs for the IP rating data are presented in Table 1. There were no significant differences between the Motion and No-Motion groups for any of the maneuvers. A reliable trials effect, however, was found for all maneuvers except the Lazy 8. In each case, the reliable trials effort was due to an improvement in performance between the first and second measured repetitions. None of the motion-by-trials interaction effects was found to be significant.

Table 1. **ANOVA Summary for ASPT Performance Evaluations Using IP Ratings**

Maneuver	Motion	Trials	Trials x Motion
Aileron Roll	.12	3.99*	2.42
Loop	1.39	24.88***	2.77
Split S	.21	13.97***	.31
Lazy 8	.88	1.50	.58
Immelmann	1.59	23.84***	2.26
Barrel Roll	.01	13.53***	.92
Cuban 8	.01	15.65***	.01
Cloverleaf	.42	4.84**	.12

*$p < .10$.
**$p < .05$.
***$p < .01$.

Results of the MANOVAs for each maneuver are presented in Table 2. Descriptive statistics and results of the stepdown univariate F-tests are presented in Appendix D. No significant effects were found for the Trial 1, Trial 2, or the combined trial data for the Aileron Roll, Lazy 8, Barrel Roll, or Cuban 8. A significant effect ($p < .10$) was obtained on Trial 1 for the Loop. The stepdown univariate F-tests revealed significant differences ($p < .10$) on the first two variables, Max G During Pullup and Pitch Rate Control. In both cases, better performance was demonstrated by the Motion group. For the second trial, the overall multivariate F-ratios failed to reach significance, as well as the individual stepdown univariate F-ratios. The same held true for the combined analysis with the exception that the

Table 2. **MANOVA Summary for ASPT and T-37 Performance Evaluations Using Special Data Cards**

Maneuver	Trial 1	Trial 2	Trials 1 & 2	T-37 Evaluation
Aileron Roll	.18	1.99	.53	.86
Loop	2.39*	.36	.89	1.02
Split S	.71	2.62*	.83	.66
Lazy 8	.22	.41	.21	1.60
Immelmann	2.87**	1.71	1.73	1.42
Barrel Roll	.63	.64	.46	2.06**
Cuban 8	.34	1.96	1.03	.93
Cloverleaf	1.03	4.09*	3.00**	1.07

*$p < .10$.
**$p < .05$.

univariate F-ratio for Max G During Pullup reached significance ($p < .10$).

For the Split S, neither the individual univariate F-ratios nor the overall multivariate F reached significance on the first trial. The same was true for the combined data from both trials. However, for Trial 2, the multivariate F did reach significance ($p < .10$). Only one of the variables, Bank Inverted Prior to Pullthrough, was signfiicant ($p < .05$) with superior performance demonstrated by the No-Motion group.

For the Immelmann, a significant multivariate F was obtained on Trial 1 ($p < .05$), but not for Trial 2 or the combined data. For Trial 1, significant stepdown F-ratios were obtained for Pitch Rate Control ($p < .10$) and Pitch at Completion ($p < .05$), with superior performance evidenced by the Motion group. Bank at Completion was also significant ($p < .10$). For this measure, however, superior performance was demonstrated by the No-Motion group. For the second trial, these differences disappeared. However, Bank Control During Pullup became significant ($p < .05$), with superior performance being evidenced by the Motion group. For the combined data, only Pitch Rate Control and Pitch at Completion produced significant stepdown F-ratios ($p < .10$), again in favor of the Motion group.

For the Cloverleaf, neither the individual univariate F-ratios nor the overall multivariate F reached significance on the first trial. The second trial produced a significant multivariate F ($p < .05$) with only one significant stepdown F-ratio ($p < .05$) for overall Bank Control. For this measure, the Motion group evidenced better performance. These differences were also found for the combined data. In addition, Pitch at the Roll Point also emerged to be significant, again favoring the Motion group.

T-37 Training Transfer Evaluations

Although it was planned that one repetition of each maneuver be flown on every sortie within the Basic and Advanced training blocks, this was not accomplished in every case. In fact, the number of repetitions varied considerably across students. It must be realized that aerobatics are not emphasized within T-37 training and are used as "confidence building" maneuvers. The only requirement is that each maneuver be demonstrated and that the student fly each task at a Fair

level. In many cases, these aerobatic sorties are used to practice other advanced contact tasks considered to be more important. For this reason, the number of repetitions varied. Consequently, for each measure taken, the value used in the data analysis was the average of all the available data.

Using the individual measures recorded on the data card for each maneuver, a MANOVA was performed. Results of the MANOVAs are also presented in Table 2. Stepdown univariate F-ratios were also computed for each variable. In addition, a priori t-tests were computed for each measure. These comparisons were between the Motion vs. No-Motion groups and the ASPT-trained groups combined vs. the Control group. Descriptive statistics and results of these analyses are presented in Appendix D.

For the Aileron Roll, the multivariate F was not significant, even though one measure, Bank Control, did have a significant ($p < .10$) stepdown F-ratio. A priori t-tests revealed only the ASPT-trained vs. Control comparison to be significant ($p < .10$), with superior performance evidenced by the two ASPT-trained groups. The Loop and Split S revealed no significant effects for the multivariate F, stepdown univariate F-ratios, or the a priori t-tests.

The Lazy 8 produced two significant univariate F-ratios, Airspeed at 360° ($p < .10$) and Pitch Control ($p < .05$), although the multivariate F did not reach significane. Again, the two ASPT-trained groups performed significantly better ($p < .05$ and $p < .01$ respectively).

The Immelmann produced no significant univariate F-ratio. However, two a priori t-tests were significant. For Pitch Rate Control, the ASPT-trained groups performed significantly better ($p < .10$) than did the Control group. For Bank Control, the Motion group performed significantly better ($p < .10$) than the No-Motion group.

The Barrel Roll yielded the only significant multivariate F ($p < .05$). Three of the individual measures produced significant stepdown F-ratios, Bank at the Inverted Position ($p < .01$), Roll Rate Control ($p < .05$), and Reference Point Alignment ($p < .01$). Each of these maneuvers was significant ($p < .01$) for the ASPT-trained vs. Control group comparison. Bank at Completion was also found to be significant ($p < .10$) for this comparison. None of the Motion vs. No-Motion comparisons was significant.

The Cuban 8 likewise produced no significant multivariate F-ratio. Two measures did produce significant stepdown F ratios: Rudder Control ($p < .05$) and Ground Track Control ($p < .10$). In both cases, the two ASPT-trained groups performed significantly better ($p < .01$ and $p < .05$, respectively) than did the Control group. No differences emerged between the Motion and No-Motion groups.

For the Cloverleaf, Airspeed Control produced a significant ($p < .05$) stepdown F-ratio, although the multivariate F was not significant. The comparison between the ASPT-trained and Control group was significant ($p < .01$). This comparison also produced significant a priori t-tests for Pitch at the Roll Point ($p < .05$) and Bank Control ($p < .10$). None of the Motion vs. No-Motion comparisons was significant.

IV. DISCUSSION

For data obtained within the simulator, two questions were of interest. First, did skill level increase in the simulator as a function of training; Second, did platform motion affect such skill acquisition? The data obtained clearly demonstrated that learning did occur. Using the IP ratings, seven of the eight maneuvers produced a significant trials effect indicating superior performance on the second measured trial. The trend for the other maneuver, the Lazy 8, was also in this direction. Although the measures obtained from the special data cards were not analyzed to test this effect, a glance at the descriptive statistics indicates increased proficiency on the second measured trial for virtually every measure.

The effect of platform motion cueing on performance in the simulator was less clear. Using IP ratings, no significant motion effects or motion-by-trial interaction effects were found for any of the maneuvers. However, analyses of the measures from the special data cards did produce a number of statistically significant effects. Unfortunately, the number of inconsistencies makes any

interpretation a matter of speculation. Of the 24 MANOVAs computed, only two reached the .05 significance level. None of the maneuvers produced a consistent effect over the two repetitions. Likewise, for the stepdown univariate F-tests, there was no instance in which a significant effect was found on each of the two trials.

Further inconsistency was noted for the same measures across different maneuvers. For example, Max G During Pullup was recorded for three maneuvers: Loop, Immelmann, and Cuban 8. For the Loop, the Motion group produced significantly better performance only on Trial 1. For the Immelmann, no differences emerged. For the Cuban 8, the Motion group produced significantly better performance only on Trial 2. Overall, for the 10 significant F-tests for the Trial 1 and Trial 2 data analyses, seven favored the Motion group, while three favored the No-Motion group. These findings, in conjunction with a lack of any motion effect for the IP ratings, indicate that platform-motion cueing does not strongly or consistently affect performance in the simulator.

Two questions were of interest for data obtained from the aircraft. First, did the skills acquired during the ASPT training enhance subsequent performance in the aircraft? Second, did ASPT training with platform motion improve such transfer? The obtained data suggested only a modest degree of transfer. Of the eight maneuvers trained in the ASPT, only one, the Barrel Roll, produced an overall significant transfer effect across the three groups. However, approximately one third of the ASPT-trained vs. Control group a priori t-tests produced significant effects. In all cases, superior performance was demonstrated by the ASPT-trained groups. An examination of group means indicated the trends favored the simulator-trained group for all except three of the measures taken. From these data, it is apparent that transfer of training did occur. However, the magnitude of the effect was not great.

Data obtained from the aircraft indicated that the addition of platform-motion cueing did not significantly enhance the effectiveness of the training. Of all the a priori t-tests comparing the Motion and No-Motion group, only one was found to be significant. Considering the number of measures, the probability of at least one comparison being significant by chance is quite high. A look at the direction of the means indicated about two-thirds favored the Motion-trained group. Again, the magnitude of these differences was small and not statistically significant.

The modest degree of transfer and the inconsistent effects of platform motion are, to some extent, the result of certain measurement and experimental control problems. The evaluation of performance presented problems in both the simulator and the aircraft. As indicated previously, system failures and unvalidated software prevented the use of data from the automated performance measurement system in the ASPT. The use of instructor judgments also presented some problems. During the ASPT training, an overall evaluation was obtained using a 12-point scale. In the instructor pretraining sessions, high agreement among raters was obtained when evaluating the precorded demonstrations. However, agreement among the flightline instructors who provided the inflight evaluations was extremely low. For this reason, overall evaluations were deleted from the T-37 sorties. In both instances, however, high agreement was obtained using the special data cards. Consequently, these were used for both the simulator and aircraft evaluations.

Despite the acceptable rater agreement using the special data cards, the question of the validity of the judgments taken remains unanswered. To the extent possible, an attempt was made to make the judgments criterion-referenced. For example, in the Aileron Roll, the desired Bank at Completion is zero, thereby making an objective error assessment possible. However, the Lazy 8 required the instructors to record airspeed at various points in the maneuver. It was assumed that correct airspeeds were indicative of the overall proficiency level on the maneuver. However, the functional relationships between the airspeed values and overall proficiency were based on analytic considerations, not empirically derived, thereby making the meaning of these measures questionable. Furthermore, one or more judgments concerning aircraft control (e.g., Pitch Rate Control) was required for each maneuver in which no objective criterion was available. And finally, the extent to which the sum of the information collected represents a true assessment of

proficiency is unknown. Unfortunately, an experimental verification of the data cards was not possible prior to the initiation of the study.

The inability to obtain high inter-rater agreement among the flightline instructors pointed to one of the experimental control problems encountered. While the IPs who provided instruction in the ASPT were relatively homogeneous in terms of their piloting and instructing experience, such was not the case for the flightline instructors who provided the transfer of training data. While some had been instructing T-37 students for varying lengths of time, others were new IPs for whom subjects in the present study represented their first students. Such heterogeneity among the flightline instructor most likely accounted for the lack of inter-rater agreement in the global evaluations of proficiency.

In addition to the inability to control the experience level of the flightline IPs, it was impossible to control the content of the seven sorties flown in the two aerobatic blocks of T-37 training. It was requested that the IP have the student fly at least one repetition of each maneuver on each sortie within a given block. However, as noted earlier, such a procedure was not followed by all of the instructors, with the result that the number of repetitions varied considerably across students. The inability to control the content of each sortie and the subsequent variability of the number of repetitions for each student undoubtedly lowered the power of the experimental design.

Despite these experimental control and measurement problems, the data collected clearly demonstrated that learning did occur in the simulator and that a modest degree of transfer to performance in the aircraft did occur. When considering the overall effectiveness of the ASPT training, the reader should be reminded that the control procedures exercised probably reduced the maximum training value that could have been achieved in a less restrained, more operational training environment. Several factors discussed in the previous study (Martin & Waag, 1978) are also applicable to the present effort. Additionally, simulation experience as a whole is quite limited regarding the effective training of these tasks. The authors are aware of only one other effort to investigate the transfer of training of aerobatic skills (Woodruff, Smith, Fuller, & Weyer, 1976). In that effort, simulator training produced only a four percent savings of time in the aircraft for a Transfer Effectiveness Ratio (TER) of .11. From these data, it is apparent that the effective utilization of flight simulation for these tasks has not been demonstrated and that efforts are required to develop more effective training procedures.

V. CONCLUSIONS

In light of the limited effectiveness of the simulator training, the question of the added training value as a result of platform motion cueing becomes academic as opposed to practical. It is clear from the data that the addition of platform motion failed to provide any systematic or practical enhancement of either performance in the simulator or the resulting transfer to the aircraft. It is apparent that the lack of force cueing information is not the reason for the limited effectiveness of the training. It may be that aerobatic skills may be more cost-effectively trained in the aircraft. Certainly within the T-37 phase of UPT in which aerobatic skills are not emphasized, such a case could be made. From an academic standpoint, the question of the added training value due to platform motion cueing is not resolved with the data from the present study. However, from an operational viewpoint, the data revealed no practical value of platform motion cueing and seriously questioned the cost-effectiveness of aerobatic simulation training within the UPT environment.

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APPENDIX A: ASPT TRAINING SYLLABUS DESCRIPTION

Table A1. **ASPT Training Task Summary**

Mission 1	Task	Repetition
Basic Airwork	Straight and Level	2
	Turn to Heading	1
	Steep Turn	2
Basic Aerobatics	Aileron Roll	22
	Split S	30
	Loop	21
	Lazy 8	11
Advanced Aerobatics	Immelmann	15
	Barrel Roll	15
	Cloverleaf	10
	Cuban 8	10

Table A2. **ASPT Mission Scenarios**

Missions	Task	Repetition
1. Basic Aerobatics	Straight and Level	1
	Turn to Heading (R or L)	1
	Steep Turn (R)	1
	Steep Turn (L)	1
	Aileron Roll (Right and Left)	Demo
	Aileron Roll (R)	2
	Aileron Roll (L)	2
	Loop	Demo
	Loop	4
	Split S (Right and Left)	Demo
	Split S (R)	2
	Split S (L)	2
	Performance Measurement	
	Aileron Roll (R)	1
	Aileron Roll (L)	1
	Loop	1
	Split S (R)	1
	Split S (L)	1
2. Basic Aerobatics	Aileron Roll (R)	3
	Aileron Roll (L)	3
	Loop	5
	Split S (L)	5
	Lazy 8	Demo
	Lazy 8	4
	Performance Measurement	
	Lazy 8	8

Table A2 (*Continued*)

Missions	Task	Repetition
3. Basic Aerobatics	Aileron Roll (R)	3
	Aileron Roll (L)	3
	Loop	10
	Split S (R)	5
	Split S (L)	5
	Lazy 8	5
	Performance Measurement	
	Aileron Roll (R)	1
	Aileron Roll (L)	1
	Split S (R)	1
	Split S (L)	1
	Loop	1
	Lazy 8	1
4. Advanced Aerobatics	Aileron Roll (R)	1
	Aileron Roll (L)	1
	Split S (R)	1
	Split S (L)	1
	Immelmann	Demo
	Immelmann	4
	Barrel Roll	Demo
	Barrel Roll	4
	Cuban 8	Demo
	Cuban 8	4
	Cloverleaf	Demo
	Cloverleaf	4
	Performance Measurement	
	Immelmann	1
	Barrel Roll	1
	Cuban 8	1
	Cloverleaf	1
5. Advanced Aerobatics	Immelmann	9
	Barrel Roll	9
	Performance Measurement	
	Immelmann	1
	Barrel Roll	1
	Cuban 8	4
	Performance Measurement	
	Cuban 8	1
	Cloverleaf	4
	Performance Measurement	
	Cloverleaf	1

APPENDIX B: DATA COLLECTION FORMS

AILERON ROLL

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
INITIAL PITCH ATTITUDE	
BANK AT COMPLETION	
ROLL RATE CONTROL	
1 2 3 4 5	
U E	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 103 ONE TIME EXPIRES AUGUST 1976

Figure B1. **Aileron Roll Data Card.**

LOOP

STUDENT | INSTRUCTOR | DATE | MISSION

PARAMETER | VALUE

MAX PULL-UP "G" FORCE

PITCH RATE CONTROL

1 2 3 4 5

U E

BANK CONTROL

1 2 3 4 5

U E

GROUND TRACK CONTROL

1 2 3 4 5

U E

OF ATTEMPTS

COMMENTS

AFHRL FORM APR 76 105 ONE TIME EXPIRES AUGUST 1976

Figure B2. **Loop Data Card.**

SPLIT S

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
INITIAL PITCH ATTITUDE	
ENTRY AIRSPEED	
BANK INVERTED PRIOR TO PULL THROUGH	
GROUND TRACK CONTROL (PULL THROUGH) 1 2 3 4 5 U E	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 104 ONE TIME EXPIRES AUGUST 1976

Figure B3. **Split S Data Card.**

LAZY 8

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
AIRSPEED	
START	
90°	
180°	
270°	
360°	
BANK CONTROL	
1 2 3 4 5	
U E	
PITCH CONTROL	
1 2 3 4 5	
U E	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 102

ONE TIME EXPIRES AUGUST 1976

Figure B4. **Lazy 8 Data Card.**

IMMELMANN

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
MAX PULL-UP "G" FORCE	
BANK CONTROL/PULL-UP 1 2 3 4 5 U E	
PITCH RATE CONTROL 1 2 3 4 5 U E	
RUDDER CONTROL 1 2 3 NONE WRONG CORRECT	
BANK AT COMPLETION	
PITCH AT COMPLETION	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 106 ONE TIME EXPIRES AUGUST 1976

Figure B5. **Immelmann Data Card.**

BARREL ROLL

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
BANK AT HORIZON/START	
BANK AT HORIZON/INVERTED	
BANK AT HORIZON/COMPLETION	
ROLL RATE CONTROL/OVERALL 1 2 3 4 5 U E	
REFERENCE POINT ALIGNMENT 1 2 3 4 5 U E	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 107 ONE TIME EXPIRES AUGUST 1976

Figure B6. **Barrel Roll Data Card.**

CUBAN 8/2ND LOOP

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
DIVE ANGLE (START 2ND LOOP)	
MAX PULL-UP "G" FORCE	
BANK CONTROL 1 2 3 4 5 U E	
PITCH RATE CONTROL 1 2 3 4 5 U E	
RUDDER CONTROL 1 2 3 NONE WRONG CORRECT	
GROUND TRACK CONTROL 1 2 3 4 5 U E	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 101

ONE TIME

EXPIRES AUGUST 1976

Figure B7. **Cuban 8 Data Card.**

CLOVERLEAF

STUDENT	INSTRUCTOR	DATE	MISSION

PARAMETER	VALUE
PITCH AT ROLL/2ND LEAF	
BANK AT HORIZON/INVERTED (2ND LEAF ONLY)	
AIRSPEED CONTROL/OVERALL 1 2 3 4 5 U E	
BANK CONTROL/OVERALL 1 2 3 4 5 U E	
GROUND TRACK CONTROL/OVERALL 1 2 3 4 5 U E	
# OF LEAVES COMPLETED •	
# OF ATTEMPTS	

COMMENTS

AFHRL FORM APR 76 100

ONE TIME EXPIRES AUGUST 1976

Figure B8. **Cloverleaf Data Card.**

APPENDIX C: DATA COLLECTION INSTRUCTIONS

As you are probably already aware, you are being asked to collect information on the performance of some students in your flight on selected basic and advanced aerobatics maneuvers. Some of the students have received prior ASPT training on these maneuvers, while others have not. We are trying to determine in as precise and quantitative manner as possible the effectiveness of this training. Since you are the best qualified to evaluate their performance and, therefore, the value of the training, we are requesting that you assist us in obtaining the required information.

This information has been requested by several agencies within the Air Force, including ATC, the Simulator SPO, and Air Staff. The data that you are taking will be used in decisions on what kind of simulators to procure. Most major commands are in the process of deciding what kind of trainers, with what capabilities and relative training effectiveness, to buy. The Human Resources Laboratory has been tasked with supplying a major portion of the data to aid in these decisions. Therefore, the data which you are being asked to collect will have far-reaching consequences.

In order to obtain meaningful information, it is necessary to collect systematic information in as standardized a manner as possible. On each sortie in the basic aerobatic block (C25XX), we need data cards filled out on the **first** attempts by the students on the following maneuvers: (a) Aileron Roll, (b) Split S, (c) Loop, and (d) Lazy 8. Thus, on each sortie, you will have taken data on four maneuvers. Likewise, during the advanced aerobatic block (C27XX, excepting their solo ride), we need the **first** attempts by the students on the following maneuvers: (a) Immelmann, (b) Barrel Roll, (c) Cuban 8, and (d) Cloverleaf.

The precise format for data collection is discussed below. If you have any questions regarding exactly what information is being requested, please ask.

There is a separate data card for each of the maneuvers previously listed. The data requested are a combination of your judgments and specific instrument values. You should be able to complete the cards accurately with little impact on your instructional duties. The data packets should be accompanied by rings allowing them to be attached to your flight suit. It is critical that you complete each card **immediately** after completion of the maneuver.

Basic Aerobatics: C25XX

1. *Aileron Roll*

a. *Initial Pitch Attitude*: As nearly as you can interpolate, note the pitch value immediately prior to the roll.

b. *Bank at Completion*: As soon as the roll is completed, record the bank value. NOTE: If the student undershoots or overshoots and then corrects, record the value of the undershoot/overshoot.

c. *Roll Rate Control*: This is a rating scale and calls upon your judgment as to how well the student maintained a constant roll rate. A score of five (5) represents the highest score and should indicate a **constant** roll rate throughout the maneuver. A score of one (1) is the worst possible and should represent excessively erratic roll rates.

2. *Split S*

a. *Initial Pitch Attitude*: As with the aileron roll, note the pitch value immediately prior to the roll.

b. *Entry Airspeed*: Note the airspeed at which the student begins the roll.

c. *Bank at Entry (Inverted)*: After the student rolls to the inverted position and before he starts the pullthrough, note the bank angle.

d. *Ground Track Control (Pullthrough)*: This is again a 5-point rating scale asking for your judgment as to how well the student maintains his ground track. A score of five (5) represents the best

performance indicated by a student who maintains continuously the proper ground track alignment. A score of one (1) would be called for if the student loses all concept of how to maintain alignment.

3. *Loop*

a. *Pullup G Force*: Record the maximum G force during the pull-up.

b. *Pitch Rate Control*: Again, a 5-point rating scale. A score of five (5) would indicate a constant pitch rate, while a score of one (1) would indicate erratic changes.

c. *Bank Control*: A score of five (5) would indicate that the student maintained wings level continuously throughout the maneuver. A score of one (1) would indicate erratic shifts in bank throughout the maneuver, or complete disregard for bank control.

d. *Ground Track Control*: Record a score of five (5) if the student maintained excellent ground track alignment and a score of one (1) if the student was erratic or lost is track completely.

4. *Lazy 8*

a. *Airspeed*: Record the airspeed value at each 90° increment of the maneuver. If the student fails to complete the maneuver, enter NA for the remaining points.

b. *Bank Control*: Again, a 5-point rating scale which will indicate how well the student maintained bank control. Since bank varies throughout the maneuver and changes are induced in order to arrive at the prescribed points, we are asking you to judge how well he did this and how smoothly he did it. A score of five (5) would indicate proper application of bank changes in a smooth manner. A score of one (1) would indicate inappropriate bank changes and/or rough, jerky inputs.

c. *Pitch Control*: As with bank control, we are asking you to judge how well the student used pitch inputs to perform the maneuver. A score of five (5) would indicate appropriate smooth inputs and a score of one (1) would indicate inappropriate and/or rough, jerky inputs.

Advanced Aerobatics: C27XX

1. *Barrel Roll*

a. *Bank As Nose Passes Through Horizon (Start)*: As the student pulls up through the horizon at the entry, note the bank angle.

b. *Bank As Nose Passes Through Horizon (Inverted)*: Again, note bank angle as nose passes through horizon. NOTE: If student achieves wings level (inverted) above the horizon and then continues with the roll, his bank angle at the point at which the nose passes through horizon is the data point we are interested in. Conversely, he may not achieve wings level until the nose has passed through the horizon. Again, we need the bank at the intersection of nose and horizon.

c. *Bank As Nose Passes Through Horizon (Completion)*: The same considerations apply for this point as the previous two entries.

d. *Roll Rate Control (Overall)*: This item is again scored on the 5-point rating scale in which you must judge constancy of roll rate. A score of five (5) indicates a smooth, well coordinated, constant roll rate. A score of one (1) indicates erratic and inconsistent roll rate.

e. *Reference Point Alignment*: On the 5-point scale, judge accurately the aircraft rotated about the student's reference point and whether the student completed the maneuver on the same point that he started the maneuver. A score of five (5) indicates a constant radius with terminal position the same as starting position. A score of one (1) indicates erratic radial control and/or the excessive deviation from terminal point.

2. *Immelmann*

a. *Pullup G Force*: As in the loop, note the maximum G force during the pullup.

b. *Bank Control – Pullup*: Judge how well the student maintained wings level during the pullup. A score of five (5) indicates a consistent wings level attitude. A score of one (1) indicates excessive deviation from wings level and/or erratic changes in bank attitude.

c. *Pitch Rate Control – Pullup*: Assess how well the student maintained constant pitch rate during the pullup. A score of five (5) indicates constant rate, while a score of one (1) indicates erratic changes.

d. *Rudder Control*: Indicate whether the student used rudder properly with three (3). Application of wrong rudder should be noted with a two (2), while no rudder should be indicated with a one (1).

e. *Bank At Completion*: Record the bank angle at the completion of the roll. NOTE: If the student overshoots or undershoots and subsequently corrects, record the overshoot/undershoot value.

f. *Pitch At Completion*: Record pitch value at the termination of the roll.

g. *Ground Track Control*: On the 5-point scale, assess how well the student maintained ground track alignment. A score of five (5) indicates continuous alignment, while a score of one (1) indicates excessive deviation and/or erratic deviation from the proper ground track.

3. *Cuban 8 – Second Loop Only*: We are interested in assessing the student's performance only during the second loop of the Cuban 8.

a. *Dive Angle (Start of Second Loop)*: After completion of the roll in the first loop until the beginning of the second loop, observe the dive angly. Record the value which represents an average of the pitch attitude during this period.

b. *Pullup G Force*: Record maximum G force during the pullup of second loop.

c. *Bank Control*: Assess the student's ability to maintain wings level prior to the roll, using the 5-point scale. Use criteria as in Loop and Immelmann.

d. *Pitch Rate Control*: Assess the student's ability to maintain constant pitch rate prior to the roll. Using the 5-point scale, apply the same criteria as in Loop and Immelmann.

e. *Rudder Control*: As in the Immelmann, record a three (3) if the student applies appropriate rudder, a two (2) if he uses wrong rudder, and a one (1) if he does not use any rudder.

f. *Ground Track Control*: Using the 5-point scale, apply the same criteria as Loop, Split S, and Immelmann.

4. *Cloverleaf*

a. *Pitch At Roll – Second Leaf Only*: Record the pitch value just prior to beginning the roll in the second leaf.

b. *Bank At Horizon – Inverted – Second Leaf Only*: Record the bank angle as the nose passes through the horizon (inverted during the second leaf).

c. *Number of Leaves Completed*: Simply note the number of leaves completed. If this value is less than four, indicate the reason on the back of the card.

d. *Airspeed Control (Overall)*: Considering the entire maneuver (or for the number of leaves completed), rate the student's ability to maintain airspeed control. A score of five (5) indicates that the student attained proper airspeed at all critical points throughout the maneuver. A score of one (1) indicates the student never came close to attaining appropriate airspeed.

e. *Bank Control (Overall)*: Considering the entire maneuver, rate the student's ability to maintain bank control on the 5-point scale. A score of five (5) indicates smooth application of aileron inputs such that the wings are maintained level during pullup, smooth roll, and wings level during pullthrough. A score of one (1) indicates excessive bank deviations and erratic inputs.

f. *Ground Track Control*: Using the 5-point scale, rate the student's ability to achieve and maintain appropriate ground tracks. A score of five (5) indicates appropriate alignment for each leaf completed, while a score of one (1) indicates excessive deviations from the appropriate ground tracks for all leaves completed.

APPENDIX D: DESCRIPTIVE STATISTICS AND DATA ANALYSIS SUMMARY

Table D1. **Descriptive Statistics for ASPT IP Ratings**

	Motion				No Motion			
	Trial 1		Trial 2		Trial 1		Trial 2	
Maneuver	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Aileron Roll	8.73	.81	8.92	1.02	8.21	1.39	9.67	1.23
Loop	7.89	1.51	9.25	1.16	6.52	2.36	9.25	1.23
Split S	6.45	2.02	8.00	1.55	6.45	1.96	8.54	1.22
Lazy 8	5.10	2.61	5.43	1.78	5.09	1.88	6.65	1.65
Immelmann	6.62	1.62	8.22	1.90	5.09	2.02	8.09	1.68
Barrel Roll	5.21	2.73	7.71	2.05	5.82	2.37	7.27	1.91
Cuban 8	6.59	1.74	8.71	1.54	6.55	2.23	8.65	1.86
Cloverleaf	7.57	2.50	8.86	2.17	6.80	2.27	8.60	1.28

Table D2. **Descriptive Statistics and Analyses for ASPT Data**

	Motion			No Motion			F-Ratios		
Measure	Trial 1	Trial 2	Trial 1+2	Trial 1	Trial 2	Trial 1+2	Trial 1	Trial 2	Trial 1+2
Aileron Roll									
Pitch Att	6.00	5.87	5.92	5.70	6.97	6.33	.12	2.06	.54
Bank Comp	6.58	3.67	5.12	5.85	2.92	4.32	.12	.38	.43
Roll Rate	3.83	4.00	3.93	3.70	4.42	4.07	.22	3.87*	.58
Loop									
Max G	.27	.17	.21	.77	.19	.45	4.15*	.02	3.21*
Pitch Rate	3.58	3.92	3.75	3.09	4.08	3.67	3.73*	.31	.12
Bank Cont	3.33	4.00	3.67	3.00	3.75	3.42	.39	.37	.51
Gnd Track	3.67	4.00	3.83	3.45	3.75	3.67	.25	.34	.25
Split S									
Pitch Att	8.04	8.92	8.51	8.09	7.12	7.41	.00	1.88	1.36
Entry A/S	7.36	13.25	10.04	2.50	9.46	7.95	.90	.16	.12
Bank Inv	10.59	6.58	8.25	10.41	3.42	6.49	.00	5.19**	.57
Gnd Track	3.00	3.62	3.33	3.36	3.79	3.63	1.04	.30	1.22
Lazy 8									
A/S Start	.00	.00	.00	.00	.00	.00	.00	.00	.00
A/S 90°	13.08	11.46	12.21	15.83	12.50	14.17	.35	.06	.51
A/S 180°	19.58	23.09	21.21	20.92	16.00	18.46	.06	.90	.35
A/S 270°	23.17	21.09	23.75	23.00	17.42	20.21	.00	.43	.45
A/S 360°	19.00	25.91	21.58	19.67	17.50	18.58	.01	1.90	.27
Bank Cont	2.50	2.91	2.67	2.58	2.83	2.71	.08	.07	.04
Pitch Cont	2.58	2.55	2.54	2.33	3.00	2.67	.61	1.69	.61

Table D2 (*Continued*)

Measure	Motion Trial 1	Motion Trial 2	Motion Trial 1+2	No Motion Trial 1	No Motion Trial 2	No Motion Trial 1+2	F-Ratios Trial 1	F-Ratios Trial 2	F-Ratios Trial 1+2
Barrel Roll									
Bank Start	6.75	3.33	5.04	8.17	4.08	6.13	.19	.11	.18
Bank Inv	35.00	22.92	28.96	19.17	12.33	15.75	1.75	.67	1.28
Bank Comp	6.08	2.75	4.42	6.67	4.50	5.58	.05	1.19	.52
Roll Rate	2.42	3.58	3.00	2.50	3.25	2.88	.04	1.60	.21
Ref Pt.	2.33	3.58	2.96	2.33	3.25	2.79	.00	.77	.27
Immelmann									
Max G	1.00	.51	.76	.90	.33	.61	.13	1.61	1.03
Bank Cont	3.75	4.33	4.04	3.75	3.58	3.67	.00	5.47**	1.88
Pitch Rate	3.58	4.33	3.96	2.92	3.75	3.33	3.30*	2.37	3.85*
Bank Comp	8.08	4.25	6.17	3.67	4.25	3.96	3.44*	.00	1.86
Pitch Comp	5.58	7.42	6.50	11.92	9.17	10.54	7.04**	.78	4.19*
Cloverleaf									
Pitch & Roll	6.00	5.25	5.63	11.67	8.75	10.21	2.85	1.59	3.99*
Bank Inv	18.00	20.83	19.42	6.67	3.08	4.88	.58	1.47	.98
A/S Cont	3.58	3.58	3.58	3.33	4.00	3.67	.25	1.35	.10
Bank Cont	3.42	4.08	3.75	2.75	3.42	3.08	2.33	4.96**	4.82**
Gnd Track	3.17	3.75	3.46	2.83	3.50	3.17	.63	.36	.81
Cuban 8									
Dive Angle	8.58	5.83	7.21	12.92	10.17	11.54	1.08	2.21	2.31
Max G	.52	.38	.43	.42	.67	.56	.15	3.01*	.58
Bank Cont	3.25	4.00	3.63	3.25	3.67	3.46	.00	.79	.30
Pitch Cont	3.33	3.67	3.50	3.50	3.92	3.71	.19	.86	.66
Gnd Track	3.08	3.92	3.50	3.17	3.75	3.46	.06	.17	.03

*p < .10.
**p < .05.

Table D3. **Descriptive Statistics and Analyses for T-37 Aircraft Data**

Measure	N/M	Motion	Control	F-ratio	t MvsN/M	t ExpvsCon
Aileron Roll						
Init Pitch	4.59	4.50	5.30	.22	.09	.66
Bank Comp	1.79	3.42	4.60	2.52*	1.56	1.82*
Roll Rate	3.87	3.88	4.00	.22	.03	.68
Loop						
Max G	.29	.35	.46	.89	.64	1.24
Pitch Rate	3.34	3.42	3.26	.21	.36	.56
Bank Cont	3.20	3.32	3.24	.11	.47	.08
Gnd Track	3.19	3.56	3.37	1.01	1.48	.01

Table D3 (*Continued*)

Measure	N/M	Motion	Control	F-ratio	t MvsN/M	t ExpvsCon
			Split S			
Init Pitch	6.02	5.06	4.45	.96	.82	1.11
Entry A/S	3.12	6.12	6.44	.31	.64	.46
Bank Inv	6.30	4.57	6.18	1.07	1.40	.65
Gnd Track	3.17	3.40	3.08	.68	.87	.82
			Lazy 8			
A/S Start	.21	.38	.00	.87	.49	1.19
A/S 90°	22.12	17.01	22.10	.75	1.04	.61
A/S 180°	22.58	22.40	17.74	.24	.02	.71
A/S 270°	20.28	16.56	23.84	1.20	.75	1.34
A/S 360°	13.03	11.27	17.55	2.72*	.67	2.26**
Bank Cont	2.97	2.83	2.71	.64	.64	.97
Pitch Cont	2.92	2.74	2.36	4.70**	1.03	2.97***
			Immelmann			
Max G	.39	.74	.95	1.19	1.40	1.22
Bank Cont	2.98	3.68	3.26	2.05	−2.08*	.23
Pitch Rate	3.36	3.62	3.04	1.96	−.96	1.79*
Rudder Cont	2.64	2.86	2.54	1.34	−1.06	1.20
Bank Comp	4.46	2.88	2.56	1.04	1.10	.92
Pitch Comp	9.49	9.09	10.39	.14	.20	−.52
			Barrel Roll			
Bank Start	5.38	2.46	4.81	.89	1.63	−.42
Bank Inv	7.71	6.73	17.22	5.98***	.41	−3.50***
Bank Comp	2.08	1.96	4.57	1.73	.11	−1.89*
Roll Rate	2.92	2.58	2.04	1.73**	1.30	2.89***
Ref. Pt.	2.89	2.80	2.06	7.26***	.34	3.85***
			Cuban 8			
Dive Angle	9.58	10.69	13.68	.88	−.39	−1.30
Max G	.36	.28	.53	.62	.56	−1.08
Bank Cont	3.35	3.30	3.14	.29	.15	.76
Pitch Rate	3.29	3.44	3.22	.37	−.56	.64
Rudder Cont	2.83	2.71	2.29	4.23**	.76	2.87***
Gnd Track	2.97	3.09	2.50	2.61*	−.41	2.27**
			Cloverleaf			
Pitch & Roll	6.32	6.35	10.24	2.04	−1.38	−2.05**
Bank Inv	6.58	6.35	7.50	.05	7.02	−.39
A/S Cont	3.20	3.32	2.50	4.92**	−.45	3.15***
Bank Cont	2.90	3.20	2.61	2.04	−1.14	1.74*
Gnd Track	2.90	3.05	2.51	1.57	−.66	1.69

*$p < .10$.
**$p < .05$.
***$p < .01$.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A transfer of training design was used to evaluate the contributions of simulator training with synergistic six-degrees-of-freedom platform motion to the acquisition of aerobatic skills in the novice pilot. Thirty-six undergraduate pilot trainees with no previous jet piloting experience were randomly assigned to one of three treatment group (n = 12): (a) Motion, (b) No-Motion, and (c) Control. Those students assigned to the Control group received the standard syllabus of preflight and flightline instruction. The students in the two experimental conditions received five sorties, in the Advanced Simulator for Pilot Training (ASPT), covering instruction on basic and advanced aerobatic tasks. All students received the same amount of training on each task, that is, a fixed number of repetitions per task. Student performance in the ASPT was evaluated periodically throughout the pretraining

Item 20 Continued:

phase by the use of Instructor Pilot ratings for overall task performance and of special data cards. Following three missions of instruction in the ASPT on the basic aerobatics tasks (Aileron Roll, Split "S," Loop, Lazy 8), the student advanced to the flightline for T-37 instruction. Upon completion of the basic block, the students returned for 2 ASPT instructional sorties on the advanced aerobatic tasks (Barrel Roll, Immelmann, Cuban 8, and Clover Leaf). The ASPT training was followed by the corresponding aircraft instructional block. Airborne performance was evaluated by the flightline instructor pilot using the same data card format used during the ASPT phase. The resulting data produced the following findings: (a) using IP ratings, no differences in simulator performance emerged between the Motion and No-Motion groups, (b) using the special data cards, no consistent differences emerged between the Motion and No-Motion groups, although several of the measures produced statistically significant effects, (c) significant learning occurred during simulator training for both groups, (d) the two groups trained in the ASPT performed significantly, although modestly, better in the T-37 than the control group; and (e) no significant differences emerged in T-37 performance between the Motion and No-Motion groups. This study indicates the need for developing better procedures for the training of aerobatic tasks in flight simulators. Although the data failed to reveal any significant or practical enhancement of training effectiveness as a result of the addition of platform motion, the modest degree of transfer makes the question of platform motion more academic than practical.